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PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

Improvements in Sources of Light comprising a High-pressure Mercury Vapour Electric Discharge and an Incandescent Filament in Series with it

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British Company, do hereby declare the nature of this invention (a communication from Patent-Treuhand-Gesellschaft für elektrische Glühlampen m.b.H., of 11/14 Ehrenbergstrasse, Berlin O.17, Germany, a German company) to be as follows:—

This invention relates to sources of light of the type comprising a high-pressure mercury-vapour electric discharge and an incandescent filament in series with it. In such combinations the incandescent filament is usually in the space between the discharge envelope and an outer jacket surrounding it. The term "mercury" does not exclude the presence of substances, additional to mercury, which may contribute appreciably to the light emitted.

In such combinations the primary purpose of the incandescent filament is usually to increase the proportion of red light in the light from the source. On a scale known to those skilled in the art, the percentage of red light in the light from the discharge is only about 1.3 in the light from the incandescent filament (which is usually underrun) at least 25%; the percentage in day-light is about 12. Consequently by mixing the light from the discharge and the filament a percentage approximating to that of day-light may be obtained.

But the luminous efficiency of the filament is much less than that of the discharge, for example 13 lumen/watt as against 40. Accordingly the increase of red is necessarily attained at some sacrifice of efficiency. In order to minimise this sacrifice, the filament is usually employed as the stabilising impedance of the discharge, instead of the usual choke or other reactive impedance. The power necessarily lost in even the best practicable reactive impedances is thereby used profitably; but since more power is always lost in a resistor than in a reactive impedance that produces the same stability, the efficiency of the combination, if the red content is increased considerably, is always much less than that of the discharge lamp alone. Further, since the filament has to carry the starting current, which is usually much larger than the operating current, it is apt to burn out quickly, so that life as well as efficiency is sacrified.

The object of this invention is to overcome these difficulties and to obtain a red content as high as those in known sources of light of the type specified but with higher efficiency and/or longer life.

This is achieved according to the invention by operating the source from A.C. with a reactive impedance in series with both the filament and the discharge, the voltage drop across the reactive impedance being preferably substantially greater than that across the filament. It is surprising that the efficiency can be increased by this means; for the reactive impedance will always absorb some power which is not converted into light. It appears hitherto to have been believed that the most favourable results would be obtained if the whole of the difference between the supply voltage and the voltage across the discharge were taken up by the filament, so that any power dissipated by this difference in voltage is dissipated in the filament. The discovery on which the invention rests is that this belief is untrue.

The reason for this surprising fact forms no part of the invention. But it appears to be two-fold. First, the use of the reactive impedance enables the proportion of the supply voltage that is applied to the terminals of the discharge to be increased; this proportion is limited, as is well known, by the tendency of the discharge to be extinguished by accidental variations in the supply voltage. Second, it decreases the ratio of the initial current during the run up to the final operating current and thus enables the filament to be operated at a higher loading in full operation without over-

loading during the run up.

The reactive impedance preferably consists of a choke in series with the filament and the discharge together with a condenser shunted across filament and discharge in series. But this arrangement is not essential. In particular the condenser may be across the discharge only, or in series with the other elements; or it may be absent altogether or there may be only a condenser and no choke in series with the discharge and filament. If it is in the preferred position its impedance at the operating frequency should be several times that of the choke.

The advantage that may be obtained from the invention will now be illustrated by one example.

The supply is from 220-volt A.C. mains. The source and its stabilising impedance are to consume 120 watts. If a high-pressure mercury-vapour lamp operating at a pressure of some 10 atmospheres were connected across the supply in series with a filament only, the voltage across it could hardly exceed 73; it would then consume 40 watts with an efficiency of about 27 lumen/watt. The filament, consuming 80 watts, would have to be underrun so that its efficiency was about 9 lumen/watt. Consequently the total efficiency would be

$$(27 \times 40 + 9 \times 80)/120 = (1080 + 720)/120 = 1800/120 = 15 \text{ lumen/watt.}$$

On the other hand if a suitable reactive impedance is used, the voltage across the discharge can be raised to 120 volts; the discharge will then consume some 73 watts with an efficiency of about 40 lumen/watt. 10 watts will be dissipated in this impedance; consequently 37 watts can be consumed in the filament, the voltage across it being some 55; its efficiency, since it is less underrun, can be 13.5 lumen/watt. The total efficiency now is

$$(40 \times 73 + 13.5 \times 37)/120 = (2900 + 500)/120 = 3400/120 = 28 \text{ lumen/watt.}$$

The percentage of red light will be reduced by the change from about 11 to 5; but 5% will be sufficient for many purposes. The percentage may be increased by the use in known manner of luminescent materials emitting red light; by this means the effective percentage of red light in the light from the discharge may be increased from 1.3 to 6.3. If this device is used in both lamps, that without the reactive impedance gives a percentage of red light

$$(6.3 \times 1080 + 25 \times 720)/1800 = 13.8\%,$$

that with the stabilising impedance gives

$$(6.3 \times 2900 + 25 \times 500)/3400 = 9.1\%$$

Since the proportion of red light in the high pressure mercury-discharge increases with the pressure during operation, still better absolute results are obtained if higher pressures in the discharge are used. But the advantage derived from the invention still persists.

Dated the 15th day of February, 1938.

NORMAN R. CAMPBELL,
For the Applicants.

COMPLETE SPECIFICATION

Improvements in Sources of Light comprising a High-pressure Mercury Vapour Electric Discharge and an Incandescent Filament in Series with it

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British company, do hereby declare the nature of this invention (a communication from Patent-Treuhand-Gesellschaft für elektrische Glühlampen m.b.H. of 11/14 Ehrenbergstrasse, Berlin O.17, Germany, a German company) and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to combinations of a source of light with circuit elements, adapted to operate from an alternating electric supply of prescribed voltage, of the type wherein the source of light is of the kind comprising a high-pressure mercury vapour electric discharge (HPMV) lamp with an incandescent filament in series with the discharge. The term "mercury" does not exclude the presence of substances, additional to mercury, which may contribute appreciably to the light emitted. The incandescent filament is usually in the space between the discharge envelope and an outer jacket surrounding it.

In such combinations the primary purpose of the incandescent filament is

usually to increase the proportion of red light in the light from the source. On a scale known to those skilled in the art, the percentage of red light in the light from the HPMV lamp (usually called the "red ratio") may be only about 1.3; in the light from the incandescent filament (which is usually underrun) it may be at least 25; the percentage in day-light is about 12. Consequently by mixing the light from the discharge with that from the filament a percentage approximating to that of day-light can be obtained.

But the luminous efficiency of the filament is much less than that of the HPMV lamp. Accordingly, if a red ratio greater than that characteristic of the HPMV lamp is to be obtained by mixing with it light from an incandescent filament, the efficiency of the combination must be less than that characteristic of the HPMV lamp. It appears to have been thought hitherto that the greatest efficiency is obtained by using the filament as the whole of the stabilising impedance that is required by the discharge, and abolishing entirely the usual choke or other reactive impedance. For the best practicable "reactive" impedance always consumes some power, which does not contribute at all to the light; it appears to have been thought that if all the power consumed is consumed in a light-giving element, the efficiency must be greater than if some is consumed in an element which gives no light.

It is to be observed that if it is decided that the stabilising impedance in series with a given HPMV lamp, consuming a given power on a given supply voltage, is to be entirely resistive (as is a filament) and is to be no greater than is required to stabilise the discharge, the relation that can be obtained between efficiency and red ratio is closely limited. For the current through the HPMV lamp and resistance and the voltage across the resistance will all be fixed; the power consumed in the resistance will be fixed. The only variable is therefore the temperature of the filament, which can be varied by varying its dimensions. For a given life, an upper limit to the temperature during normal operation is set by the overloading of the filament during the initial stages of the run-up; this limit is well below that at which the filament would normally be operated alone in an incandescent lamp. Within the range of temperature thus available, the efficiency and the red ratio of the combination increase together with rise of temperature. Accordingly the temperature is usually adjusted so as to give, at least approximately, both the maximum efficiency and the maximum red ratio that are attainable at all for a given life, subject to the condition that all the stabilising impedance is to be resistive.

The object of this invention is to remove this limitation and to enable greater efficiency for a given life to be obtained together with a red ratio, which though necessarily less than that obtainable with lower efficiency, is yet much greater than that of the HPMV lamp at all and is known to be sufficient for many purposes, for example a red ratio of 5%. In making comparisons to ascertain whether the object of the invention is attained, the HPMV lamp must be of the same commercial type and the filament of the same material in both the states compared.

The object is attainable because the aforesaid belief has been found to be untrue. It is not true that the addition to the resistive filament of a reactive stabilising impedance, which must consume some power without emitting light, necessarily decreases the maximum efficiency.

The reason for this fact forms no part of the invention. But it appears to be two-fold. First, the use of the reactive impedance enables the proportion of the supply voltage that is applied to the terminals of the discharge to be increased; this proportion is limited, as is well known, by the tendency of the discharge to be extinguished by accidental variations in the supply voltage. Again the ratio of the initial current during the run up to the final operating current can be decreased, so that the filament can be operated at a higher loading in full operation without over-loading during the run up.

According to the invention the aforesaid object is attained by including among the said circuit elements at least one which both has a reactive impedance and is in series with both the filament and the discharge, the R.M.S voltage drop across the said reactive impedance in full operation being not much less and preferably somewhat greater than that across the filament. The presence of other reactive elements, not in series with the discharge, is permissible and often desirable.

The choice of the reactive circuit element(s) can be made by the combination of calculation with trial that is usual in designing circuit elements to be associated with HPMV lamps. The elements commonly used may be adapted. Thus a simple choke (less often a condenser) in series with the discharge is often used, and may be employed. But it is generally preferable to use in known manner

both a choke and a condenser. The condenser and choke may be both in series with the HPMV lamp and the filament; or the choke may be in series with the HPMV lamp and filament, and the condenser in parallel either with the filament or with the HPMV lamp or with both. A choke in series with the load (i.e. the filament and discharge in series) can be replaced by its known equivalent, namely the leakage reactance of a stray-field transformer to whose primary the supply is connected and from whose secondary the load is supplied. On the other hand the secondary of a close-wound transformer from which the load is supplied is not to be regarded as a reactive impedance in series with the load; for, as is well known, the impedance of the secondary of such a transformer does not affect the operation of the combination, except in so far as it is involved in the transformation ratio of the transformer.

The two preferred alternatives are shown in Figures 1 and 2 of the accompanying drawing. In each figure, 1 is the HPMV lamp, 2 the incandescent filament, 3 the choke, and 4 the condenser, 5 the terminals to be connected to the supply. In Figure 1 the condenser is in series with the choke, in Figure 2 it shunts both the lamp 1 and the filament 2. In Figure 2 the impedance of the condenser at the operating frequency must, of course, be substantially greater than that of the lamp and the filament in series.

It will be seen that, if the HPMV lamp and filament were replaced by a HPMV lamp alone, the arrangements shown in Figures 2 and 1 would be respectively those described and claimed in Patent Specifications Nos. 486,586 and 491,070. The principles of design set forth in those specifications will provide, to those skilled in the art, a sufficient guide to appropriate values of the inductance of the choke and the capacity of the condenser.

The advantage that may be obtained from the invention will now be illustrated by one example.

The supply is from 220-volt A.C. mains. The source and its stabilising impedance are to consume 120 watts. If a HPMV lamp operating at a pressure of some 10 atmospheres were connected across the supply in series with a filament only, the voltage across it could hardly exceed 73; it would then consume 40 watts with an efficiency of about 27 lumen/watt and a red ratio of about 1.3%. The filament, consuming 80 watts, would have to be underrun so that its efficiency was about 9 lumen/watt and its red ratio about 29%. Consequently the total efficiency would be

$$(27 \times 40 + 9 \times 80)/120.$$
$$= (1080 + 720)/120 = 1800/120$$
$$= 15 \text{ lumen/watt},$$

and the total red ratio about 12%.

On the other hand if a suitable reactive impedance is used, the voltage across the discharge can be raised to 120 volts; the discharge will then consume some 73 watts with a higher efficiency, namely about 40 lumen/watt; for it is known that the efficiency of a HPMV lamp increases rapidly with the watts consumed, when the watts are so low; but the red ratio will still be about 1.3%. 10 watts will be dissipated in the impedance; consequently 37 watts can be consumed in the filament, the voltage across it being some 55; its efficiency, since it is less underrun, can be 13.5 lumen/watt; its red ratio will be about 25%. The total efficiency now is

$$40 \times 73 + 13.5 \times 37)/120.$$
$$= (2900 + 500)/120 = 3400/120$$
$$= 28 \text{ lumen/watt, and the red ratio about}$$
5%.

The red ratio will be reduced by the change from about 12 to 5; but, as has been said, 5% will be sufficient for many known purposes. For these purposes, the increase in efficiency will greatly outweigh the decrease in red ratio.

The red ratio may be increased by the use, in known manner, of luminescent materials emitting red light; by this means the effective red ratio light in the light from the discharge may be increased from 1.3 to 6.3%. If this device is used in both sources, that without the reactive impedance (the red ratio of the filament being again 29%) gives a red ratio.

$(6.3 \times 1080 + 29 \times 720)/1800 = 15.4\%$.

that with the stabilising impedance (the red ratio being again 25%) gives

$(6.3 \times 2900 + 25 \times 500)/3400 = 9.1\%$.

Since the red ratio in the high-pressure mercury-discharge increases with the pressure during operation, still better absolute results are obtained if higher pressures in the discharge are used. But the advantage derived from the invention still persists; the efficiency obtainable when the reactive element is included will still be greater, for a given life, than when it is absent.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A combination, of the type specified, of a source of light with circuit elements adapted to operate it from an alternating electric supply of prescribed voltage, wherein the said circuit elements include at least one which both has reactive impedance and is in series with both the filament and the discharge, the R.M.S. voltage across the said element in full operation being not much less (or preferably somewhat greater) than that across the filament whereby the red ratio of the combination is much greater than that of the HPMV lamp alone and the luminous efficiency of the said combination is greater for a given life than it could be if no circuit element had reactive impedance, the HPMV lamp being in both cases of the same commercial type and the filament of the same material.

2. A combination according to Claim 1 wherein the said circuit element is a choke.

3. A combination according to Claim 2 comprising also a condenser in series with the said choke, the discharge and the filament.

4. A combination according to Claim 2 comprising also a condenser in series with the choke but in parallel either with the HPMV lamp or with the filament or with both.

Dated the 18th day of November, 1938.

NORMAN R. CAMPBELL,
For the Applicants.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1939.

[This Drawing is a full-size reproduction of the Original.]

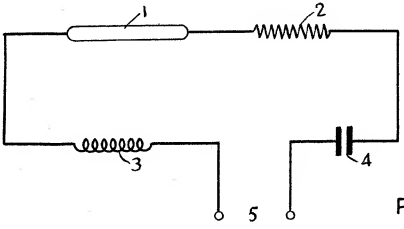

FIG. 1

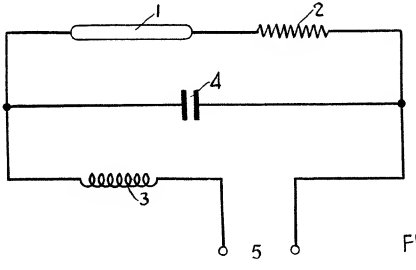

FIG. 2

Malby & Sons, Photo-Litho